GRASSROOTS JOURNALS

ISSN 2564-4653 | 04(1&2) June & Dec 2024

AGROBIODIVERSITY & AGROECOLOGY | 04(1&2) JUNE & DECEMBER 2024

Published by The Grassroots Institute (Canada) in partnership with University "Lucian Blaga" from Sibiu (Romania) and Fondacija Alica Banja Luka (Bosnia i Herzegovina). Website: https://grassrootsjournals.org/aa

M – 00465 | Review Article

Overview of Maize and Wheat Genetic Resources Preservation and Sustainable Use in Bosnia and Herzegovina

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How to cite this paper: Kondić, D. and Đurić, G. (2024). Overview of Maize and Wheat Genetic Resources Preservation and Sustainable Use in Bosnia and Herzegovina. *Agrobiodiversity & Agroecology*, 04(1&2): 46-62. Doi: https://doi.org/10.33002/aa041203

Received: 11 September 2024
Reviewed: 21 November 2024
Accepted: 29 November 2024
Published: 31 December 2024
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Editor-in-Chief
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Abstract

Cereals, primarily wheat and corn, make up a significant part of the diet in Bosnia and Herzegovina. Cereal landraces are still an important part of the global agrobiodiversity in the country, although the maize and wheat landraces, were reduced from the sowing areas, in the second half of the 20th century, as in many other countries, because of the introduction of high-yielded cultivars into production. Considering the turbulent history, in addition to the industrialization that was carried out in the second part of the 20th century, as well as the migration of humans from the countryside to the cities, all together contributed to the loss of many local populations of local maize and wheat landraces. However, during and after the 2000s, several collection missions were carried out. Different activities started and the collected accessions were stored in gene banks. In the country, there is only one breeding institute today that deals with maize and wheat breeding and selection, which makes this country constantly dependent on imported seeds. Cereal genetic resources are bearers of good traits, such as resistance to stress conditions, but also as a material that carries some undesirable properties. These genetic resources should be seen also as a part of the common heritage and should be preserved and maintained for the use of current and future generations.

Keywords

Landraces; Varieties; Genotypes; Collecting mission; Gene banks

1. Introduction

Bosnia and Herzegovina (BiH) is a southeastern European country positioned in the centre of the Balkan Peninsula. It borders Croatia to its north and west, Serbia to the east, and Montenegro to the southeast, and the south it opens onto the Adriatic Sea at a length of 20 km.

BiH is rich in natural resources, as well as a rich in history. This country was part of different states throughout history. After World War I, BiH became part of the newly created Kingdom of Serbs, Croats, and Slovenes (Kingdom of Yugoslavia from 1928). It was one of the six constituent republics of the Socialist Federal Republic of Yugoslavia from 1945 until 1992 (Garding, 2019). Since the

last war (1992-1995), BiH as an independent state constitutes two administrative parts: the Republic of Srpska, and the Federation of BiH. From 2000 Brčko District is established as a condominium of two entities. During this history, BiH was affected in every sense by economic and social processes that include agriculture (Đurić and Golub, 2018).

BiH has a land resource of a total area of 5,113,000 hectares of which 2,444,000 hectares (or 47.8%) are agricultural land. Of this land area, approximately 1,250,000 ha are in the territory of the Republic of Srpska and 1,194,000 in the territory of the Federation of BiH. The Federation of BiH has 0.51 ha per inhabitant, and the Republic of Srpska has 0.93 ha per inhabitant (Agency for Statistics of BiH, 2016).

According to UNFCCC, BiH has the temperate continental climate type, which is represented mostly in the northern and central parts of BiH; the sub-mountainous and mountainous type (over 1000 m) and the Adriatic (Mediterranean) and modified Adriatic climate type, which represents in coastal area and includes the Herzegovinian lowlands. The lowland area of northern BiH has a mean annual temperature of between 10°C and 12°C, and in areas above 500 m, the temperature is below 10°C. The mean annual air temperature in the coastal area ranges between 12°C and 17°C. Average annual precipitation in BiH is about 1,250 mm, with large differences depending on the area and year. Also, agriculture is an important and vulnerable economic sector in BiH, given the climate sensitivity of the sector, the share of agriculture in the economy (7% of the GDP), the number of people employed in the sector, and the closely related socio-economic issues of food security (UNFCCC, 2013).

BiH belongs to a group of countries considered highly vulnerable to climate change (Kreft and Eckstein, 2014). Global warming and predictions of climatic changes additionally put breeding for drought tolerance in the focus of breeding programmes for maize (Babić *et al.*, 2015). Although maize originated from Mexico (Matsuoka *et al.*, 2002) and wheat from the Middle East (Salamini *et al.*, 2002), these essential field crops were introduced to the Balkan Peninsula, including the region of BiH, where they adapted to the climatic conditions. Over time, they have become some of the most important cultivated plant species for human and animal nutrition in BiH. Because of these facts, it is essential to continue conducting collection missions to preserve their genetic diversity. However, as maize is a monoecious plant species, it is challenging to isolate these local populations from other maize varieties and hybrid maize, which can influence their traits. This challenge complicates the process of morphological characterization and evaluation, potentially discouraging research efforts on these valuable populations.

By analyzing published findings on the genetic resources of maize and wheat maintained in BiH, the aim of this research was to prepare a comprehensive overview of the state of these resources, spanning from the 20th century to the present day.

2. Overview of Maize and Wheat Production

Maize (*Zea mays* L.), together with wheat (*Triticum aestivum* L.), has a significant place in the sowing and production structure in BiH. Since 1951, the share of crop production in total agricultural production in BiH was about 50%. This level of production almost was able to provide the food needs of people and

domestic animals, as well as processing capacities. In BiH, maize was sown on an area of 371,288 ha or 42.2% of the total sown area of arable crops, and the average yield was 3,800 kg ha^{-1}. Wheat was sown in an area of 190,836 ha or 21.6% of the total sown area in Bosnia and Herzegovina or 10.39% of the area under wheat in former Yugoslavia. Winter wheat was mainly represented, and much less spring cultivars (Anonymous, 1956).

According to the population census in 1953, there were 2,847,459 inhabitants in BiH (Analysis of the population situation in BiH, 2020). According to the 2013 population census, BiH has 3,531,159 inhabitants. Today, BiH does not produce maize and wheat in the quantities it needs to feed people and domestic animals. At the time of the census (2013) BiH 57.3% lived in rural areas and 42.7% in urban areas (Agency for Statistics of BiH, 2013). For comparison, in a five-year average (2019-2023) in BiH the maize production was on a sowing area of 161,708 ha, with an average grain yield of 6,100 kg ha^{-1}, and wheat was produced on a sowing area of 59,641 ha with an average yield of 4,600 kg ha^{-1}. Comparing the period until 1951 and the period until 2023 in terms of maize and wheat production, it is clear that now the area under maize production has decreased by 209,580 ha, and under wheat production by 132,195 ha, while for the same period, the human population increased by 683,700. Modern wheat cultivars and maize hybrids are dominantly produced in the sown areas in BIH. Moreover, in our country, there is no recorded data on the sown areas under maize and wheat genetic resources (old varieties, local populations, and landraces).

A shift in agricultural policies was recorded in the 1970s when much attention was paid to the development of agriculture and rural areas. The plan was to increase the intensity of production through higher yields and generally increased productivity. Investment in land melioration was one of the focus areas of this master plan. In the 1980s, Yugoslavia was plunged into a deep economic crisis, which affected investments in agriculture and the effective implementation of the planned investment programs (Zurovec *et al.*, 2015). Everything that affected the economy including agriculture in former Yugoslavia also had consequences for the economy and agriculture in BiH.

The agricultural sector suffered enormous damage during the civil war in BiH (1992-1995). The post-war international programs of reconstruction and restoration focused on basic rural infrastructure and housing and, the purchase of agricultural machinery and inputs, seeds and fertilizers for the reconstruction and rehabilitation of crop production. It was more of a social aid to local people than a serious investment in the revitalization of agriculture, with the main objective of returning displaced populations to rural areas (Ivanković *et al.*, 2006).

According to the Agency for Statistics of BiH, of approximately 1,000,000 hectares of arable land in BiH maize was sowing at approx. 13%. Also, maize is one of the major crops in the European Union (EU-28) which shares about 21% of total cereal production (Krol-Badziak *et al.*, 2021). Climate change is characterized by rising temperatures and changes in precipitation which would have mostly negative impacts on maize yields (Zhang *et al.*, 2021).

In BiH wheat is an important commodity, both culturally and strategically. It is used to produce main staple food, like bread which is key for ensuring food security in the country. Yet, wheat accounts for only a small share of agricultural GDP (around 5%) and domestically produced wheat makes up for only a small portion of wheat consumption in the country. The major part of the demand is met by large imports from Hungary, Serbia and Croatia. After establishing a free

trade agreement (in 2003, revised in 2019), Turkey became a main export destination for wheat. Wheat in BiH is mostly produced by small family farms averaging 2-5 ha, with low use of fertilizers, chemicals, and certified seeds, by applying relatively old crop and post-harvest management practices. As a result, wheat quality and yields are low (between 3000-4000 kg ha^{-1} per ha compared to 5,000-6,000 kg ha^{-1} of average wheat yields in the European Union over the same period) (FAO, 2020).

Wheat consumption in BiH is on average 174 kg per capita, equivalent to flour of 131 kg per capita. Wheat sowing areas in the Republic of Srpska represent about 2/3 of the total wheat sown area in BiH and production of 60-76% of total BiH wheat production. Between 250,000 and 400,000 tons of wheat are imported annually in BiH (Ostojić *et al.*, 2020).

3. State of Maize and Wheat Genetic Rresources in BiH and the Possibility of Sustainable Production

Biological diversity, i.e., the diversity of living organisms – within and between various species and ecosystems, is an important resource for human subsistence and plays a key role in sustainable development including agriculture (Đurić *et al.*, 2012). Globally, less than two-thirds of crop production (on a mass basis) is allocated to human food, versus 35% to animal feed, and 3% to bioenergy or other industrial products (Foley *et al.*, 2011). Genetic resources are significant in terms of providing food, medicine and other products for the human population, and at the same time, they represent the cultural and historical heritage of humans as well as the essential value of nature itself (Đurić, 2019). The state of genetic resources in BiH was largely determined by the conventional agricultural production of high-yielding plant cultivars on the one hand and society's attitude towards its heritage on the other. BiH is obliged to apply the United Nations Convention on Biodiversity (CBD) and other international agreements and conventions that protect the environment and define measures to achieve the goals of sustainable development (CBD-UNDP, 2019) (Đurić and Mićić, 2023). Furthermore, BiH has undertaken to harmonize the agricultural policy and the rural development policy with the corresponding policies at the EU level (Mićić, 2019).

Since the 1900s, some 75% of plant genetic diversity has been lost as farmers worldwide have left their multiple local varieties and landraces for genetically uniform, high-yielding varieties. More than 90% of crop varieties have disappeared from farmers' fields. Half of the breeds of many domestic animals have been lost. The above indicates the importance of the collection, description, conservation and utilization of genetic resources. For the conservation of maize and wheat in gene banks, two strategies are applied, *ex-situ* in gene banks, and *in-situ* which include farm management and maintaining the vitality of the crops by growing them in the conditions where they developed their characteristic properties.

Today, intensive agriculture in BiH, as in other South East European countries and entities mostly uses modern commercial varieties of crops for production. In certain areas, such as mountain and remote areas, traditional varieties still play a role in less intensive agriculture and can be found in local markets and households and on restaurant tables. In BiH, cereal landraces are threatened by commercial varieties, although some local landraces of wheat and

rye still exist. In general, maize seems to be the cereal with the greatest biodiversity in the region, also due to the demand for its use in traditional cooking and traditional festivities (Rivera *et al.*, 2018). The whole region of South Eastern Europe is still rich in agricultural biodiversity, represented by local landraces. This fact was supported by the result of conducted collecting missions during 2009 and 2010, where 867 accessions of maize and cereal local landraces were collected (Simeonovska *et al.*, 2013). Maize landrace originated from locations placed at higher altitudes, mainly from Montenegro, southern parts of Serbia, including Kosovo, and to a lesser extent, from FYR Macedonia and BiH belong to extra early and early maturity groups (Babić *et al.*, 2015). Early maize genotypes better tolerate higher planting density and pass faster phenological phases, avoiding the critical period of drought during the vegetation period which results in lower grain moisture at harvest. The breeding of early maturing maize germplasm is an essential part of the management strategy for current and future maize production in terms of increasing mechanized harvests and reducing production costs and risks (Kosgey *et al.*, 2013; Li *et al.*, 2021).

The first organized collecting mission of maize landraces in former Yugoslavia, of which BiH was also a part, started in the 1960s. The most detailed description of Yugoslavian maize landraces was done by Pavličić and Trifunović (1966). They have classified all collected maize populations into 18 agroecological groups using the method proposed by Anderson and Cutler (1942). The agro-ecological maize groups originating from different regions of Yugoslavia are: Montenegrin flints, Bosnian early dents, Kosmet flinty dents, Macedonian flints, Eight rowed corn type of North Eastern America, Derived flints, Mediterranean flints, Small-kernelled flints, Eight rowed soft dents, Romanian flints, Large-eared flints, White flinty dents Moravac, Dent type of USA corn belt dents, Derived dents, Dent type of South East USA, Serbian dents, Flinty dents and Denty flints (Mladenović, Anđelković and Ignjatović, 2012). Landraces and indigenous varieties (primitive varieties, farmers' varieties, traditional varieties, local varieties, folk varieties) constitute an important reservoir of genetic diversity, conferring tolerance to abiotic and biotic stresses, and providing superior nutritional and sensory quality products as well as stability of performance in adverse environments (Marone *et al.*, 2021; De Jonge *et al.*, 2021).

The first national programme for PGR in Yugoslavia was initiated in 1988. Its realization began in 1989 when the federal project "Establishment of Plant Genebank, as the Yugoslav Federal Institution" started with the participation of 26 scientific research institutions. Four research centres from BiH were involved in these activities. The construction of the plant gene bank started in 1990 (Yugoslavia: country report to the FAO International Technical Conference on plant genetic resources, 1996). This Yugoslavian project covered inventorying, collecting, identification, multiplication, characterization and establishing a Plant Gene Bank. When the war in former Yugoslavia started in 1991, many activities inherent in the conditions of peacetime reality unfortunately stopped (Đurić and Golub, 2018; Drkenda and Zečević, 2018). Before the war in BiH (1992-1995), the inventory was largely completed and documented using Multi-crop Passport Descriptors (MCPD). Unfortunately, a large proportion of the records were lost during the war. In the case of some institutes, the data from the collecting missions was destroyed, and in some institutes, it was preserved or preserved by the researchers who worked on the collecting activities (Đurić and Golub, 2018).

The PGR activities in BIH continued with the project "South Eastern European Network on Plant Genetic Resources – SEEDNet" (2004-2014) implemented by the Swedish International Agency for Cooperation and Development (Sida). As a result of this project, two public gene banks were formed in BIH, i.e. the Gene Bank at the University of Banja Luka and the Gene Bank at the University of Sarajevo (Đurić and Golub, 2018).

There are two entities programs for plant genetic resources (PGR) in BiH, The Program of PGR Preservation in the Republic of Srpska (RS Program), and The Operational Plan for PGR conservation in the Federation of BiH (hereinafter referred to as OPPG FBIH) (Rivera *et al.*, 2018). RS Program was adopted by the National Assembly of the Republic of Srpska (hereinafter referred to as Programme) in June 2008 ("The Official Gazette of the Republic of Srpska" 59/08). The main objective of the Programme is the effective management of PGR through carrying out continuous field inventories and collecting, evaluation, exchange and conservation of germplasm. All activities were carried out by six crop-specific (cereals and maize, vegetables, fruits and *Vitis*, fodder crops, medicinal and aromatic plants, and industrial crops) and two intercrossed working groups (documentation and information, public awareness). The collected accessions were being prepared for storage at low temperatures through processes such as seed cleaning, seed germination tests (according to ISTA rules 4), drying to the optimal moisture level (3-7%) in drying chambers at low temperatures and at low moisture level in the chamber (-25°C and 10-15% relative moisture), then seed packing in three-layered aluminium bags and storing in freezers at -18 °C (Đurić and Golub, 2018).

Table 1: The *ex-situ* conservation status of wheat and maize accessions in gene banks in BIH (from Drkenda and Zečević, 2018; Đurić and Golub, 2018)

Genebank	Crop	No. of accessions	Complete document %	Characterized %	Evaluated %	Multiplied %	No. of duplicates in another
Republic of Srpska	Maize	95	100	30	30	90	87
	Wheat	172	90	10	10	95	172
	Spelt	12	100	10	10	90	5
Federation of BIH	Maize	100	70	-	70	-	-
	Wheat	17	70	-	70	-	-
	Spelt	-	-	-	-	-	-

The OPPG FBIH there were established seven crop-specific working groups (WG): cereals and maize, fruits and *Vitis*, vegetables, medicinal and aromatic plants, industrial plants, documentation and IT. Besides these seven WGs, there were defined three ad hoc WGs: fodder crops, ornamental plants, and wild relatives. In the Gen bank, seeds of more than 100 cereal and maize accessions are stored at -20°C. As the most important genotypes of maize for conservation, sustainable use as well as for breeding could be selected (Bosanac, Crveni, Kokičar, Osmak, Sitni žutac) (Drkenda and Zečević, 2018). There are more than 300 stored maize and wheat accessions in two gene banks in BiH (Table 1).

Figure 1: a) Maize multiplication in Community Seed Bank (CSB) of Foundation Alica in 2024: family farm Makarević in the Doboj region (from left to the right: Danijela Kondić, Mahira Makarević and Gordana Đurić); b) Different coloured maize kernels of accessions in Community Seed Bank (CSB) (Orig. Danijela Kondić, 2024)

Wheat is much more represented in the lowland areas, where the selected new cultivars are dominant, but it is also possible to find the material that was cultivated before the Second World War. These old varieties are characterized by a small genetic potential and greater protein content. In the mountainous areas of FBIH the old wheat genotypes can be found planted together with rye. About 17 different genotypes of wheat were stored in the Gen bank. The most important genotypes of wheat for conservation, sustainable use and breeding are two genotypes of soft wheat and two genotypes of hard wheat (Drkenda and Zečević, 2018). The intensive commercial production of maize is mostly present in the low-land area of the northern part of FBIH as well as in the valleys of the rivers Sava, Una, Bosna, Drina, Spreca, etc. In maize production, domestic maize genotypes present early and middle vegetation lengths. Domestic maize populations have mostly white and yellow grains with a lower genetic potential of yield (some of them may also possess red grains), but they have significantly higher protein content and because of that are predominantly used for human nutrition. Sweet corn and popcorn are partially present in maize production, where the popcorn varieties have different shapes and some of them also have a local origin.

Based on the morphological characterization of 31 maize landraces originally from the Republic of Srpska it was concluded that the tested maize genetic resources were morphologically different, not only based on grain colouring (11 white, 7 yellow and 13 yellow-purple landraces) but also according to other tested traits (Kondić, Đurić and Antić,, 2017).

In 2017 year 63 early local landraces were chosen for crossing with two divergent early testers, 102NS (Stiff Stalk Synthetic-Iowa-Dent BSSS-ID; dent type) and 14NS, representing the early flint heterotic group (of the F2 inbred line type). The landraces were collected in the hilly and mountainous area of the former Yugoslavia. The research was conducted in Serbia, and maize landraces originating from BiH had the following grain yields: accession 1962 (3,678 kg ha^{-1}), accession 466 (2,766 kg ha^{-1}), accession 1379 (2,119 kg ha^{-1}), accession 1586 (2,589 kg ha^{-1}), accession 1367 (3,554 kg ha^{-1}), accession 1972 (5,503 kg ha^{-1}), accession 2249 (7,738 kg ha^{-1}) and accession 1945 (4,445 kg ha^{-1}) (Babić *et al.*, 2022). Local maize populations are very significant due to their adaptation to certain growing conditions, but they also contain undesirable properties, which require many years of work their repair (Anđelković, Babić and Kravić, 2017).

The yellow flint landrace originating from BiH excelled in amino acid composition as it had pronouncedly the highest contents of leucine and phenylalanine, but also significantly higher contents of most of the other analyzed amino acids (Vančetović *et al.*, 2020). The majority of maize landraces originated from the western Balkan area and showed significant adaptability and stability under different climatic conditions. They can be used as invaluable source material for improving or/and developing parental lines of hybrids that can adapt to variable water stress in unpredictable environmental conditions (Anđelković *et al.*, 2016).

In Yugoslavia, wheat breeding activities began before the First World War in selection stations, agricultural experiments, and agricultural schools in Zemun and Zagreb. The concrete results were various varieties (varieties of populations) that were named after the places where they were created, such as Rumska, Križevačka, Beljska, Maksimir, Zemun, and other selections. As a result of those first breeding activities, the State Commission for Recognition of Varieties, after a 3-year examination in 1953 decided on the recognition of the originality of a few newly bred white wheat varieties such as Novosadska 1439/3 and Bankut 1205 which are multiplied selection from Hungarian populations. Until the mid-1950s, wheat varieties hardly had a higher yield than 1000 kg ha^{-1}. From the middle to the end of the 1960s, a new series of winter wheat cultivars from the Institute of Agriculture and Vegetables Novi Sad was recognized: Bačka (1964), Brkulja-4 (1964), Pannonia (1964), Crvena Zvezda (1967), Novosadska-32 (1967) and Danube (1968). These varieties were not widely represented in production, although they were more productive than the varieties recognized in the previous period (Novosadska 1439/3, Novosadska 1446 and Bankut 1205). Because of high-yielding, semi-dwarf, Italian varieties were introduced in the meantime, which have been since 1956 dominated production. Italian varieties such as Autonomia, San Pastore, Produtore, Leonardo, Libellula, etc. have greatly contributed to the increase in production and freed the country from importing wheat. During the period of dominance of Italian varieties (1958-1970), the average yield in Vojvodina increased by more than a ton per hectare. Although Italian varieties contributed significantly to the improvement of wheat production, due to insufficient resistance to low temperatures and very poor quality of grain, flour and bread, they could not represent a permanent solution in wheat production (Denčić *et al.*, 2006). A great contribution to the superiority of winter wheat varieties from Novi Sad was made by genes that determine resistance to prevalent diseases. Genotypes, which were determined under conditions of

artificial inoculation and in the field to have resistance to the mentioned pathogens, were used by breeders as sources of resistance. In the beginning, these were American varieties and lines from Kansas and Purdue University (Indiana), such as Red Coat, Selkirk, KS-56 R-386, Purdue -5369-A-4114, CI13170, etc. They were crossed with then widespread Italian varieties, Fortunato, Producer, Mara, and San Pastore (Borojević, Borojević and Mikić, 1963).

Italian wheat varieties did not completely satisfy the demands of wheat production, so wheat breeders in the former Yugoslavia started developing high-yielding cultivars that would be more suitable for the local climatic conditions (especially winter hardiness) and the requirements of the milling and baking industry. The Italian wheat cultivar San Pastore, the Russian cultivar Bezostaja, and the old Hungarian cultivar Bankuty played a significant role in the breeding of wheat (Borojević and Borojević, 2005).

Former Yugoslavia had 13 wheat breeding institutions and even more wheat breeding programs. Several concepts have been developed with the purpose of determining the most effective way to create high-yielding wheat cultivars (Borojević, 1971). High-yielding wheat cultivars replaced local wheat populations that did not have a satisfactory grain yield.

Examination on 10 obsolete wheat cultivars (Brkulja, Ličanka, Partizanka, Vuka, Talijanka, Šiđanka, Orašanka, Lozničanka, Dokučajevskaja and Nemcitaevskaja) and 2 local population (Podrašnica and Previja) that was performed in 2015/16 and 2016/17 in agroecological conditions of Banja Luka imply that obsolete cultivars Brkulja and Šiđanka bear some promising grain characteristics at the morphological level. Also, obsolete cultivars Partizanka (12.88%) and Vuka (12.38%) obtained the highest protein content. Based on the protein content remaining genotypes can be categorized as genotypes with weak flour that can be used for the production of biscuits and cakes (Kondić *et al.*, 2020).

BiH for many centuries has been a crossroad of various civilizations and religions, which made BiH's kitchen one of the richest in Europe, even in the world. Food in BiH is rather fatty and delicious rather than healthy and light. It can be considered a food for real gourmands (Samardžić *et al.*, 2021). Bread is most often made from wheat and corn flour (a speciality is bread baked on a stone plate and under a honeycomb). Pies occupy a significant place in traditional cuisine and the piecrusts are home-made, thanks to the skilled hands of local housewives. Cicvara "dish with honey, a favourite speciality of Herzegovinians, is made from wheat flour and seasoned with cheese, cream, butter or oil. "Pura (kačamak)" is prepared from corn flour (with salt, cheese and butter) and eaten with cream or sour milk. "Prince" is made from wheat flour, fried in oil and served warm (with cheese, young cream or marmalade). "Prijesnac" is made from wheat or corn flour (with milk, cream, cheese, and eggs) (Vukojević *et al.*, 2021).

By highlighting the rich heritage of BiH's geographically unique products, these insights have the potential to inspire and empower producers, local communities, traders, importers, and investors to fully unlock the value of "geographical indications (GI)". Emphasizing the significance of these labels can pave the way for the expansion of geographically branded products in both domestic and international markets. Moreover, such research can serve as a vital tool for policymakers in crafting national programs aimed at boosting rural employment, enhancing the competitiveness of local products, and strengthening

ties between the agricultural sector and the geographic identity of BIH (Brenjo *et al.*, 2023). According to Vukojević *et al.*, (2021), Herzegovina has immense potential to establish itself as a premier destination for gastronomic tourism, recognized on an international scale. By fostering collaboration among food producers, winemakers, and the tourism sector, a unique form of tourism can emerge—centred around the culinary and cultural treasures of rural areas and vineyards. These settings can transform into immersive destinations where visitors experience the rich gastronomic and cultural essence of Herzegovina, becoming a key motivator for their travels. The growth of gastronomic tourism offers significant economic and social benefits, including enhanced regional competitiveness. By better utilizing Herzegovina's natural and traditional resources, this development can also play a vital role in addressing the pressing issue of rural depopulation, breathing new life into Herzegovinian villages and preserving their heritage for generations to come.

4. Conclusion

In BiH, maize and wheat genetic resources are poorly researched, with limited data on their distribution and insufficient characterization and evaluation. There are no official statistics on the production of local populations of these crops, nor are there active breeding programs aimed at their improvement. However, maize continues to have cultural and agricultural importance in BiH, primarily due to its use in traditional dishes, which ensures its continued production. Compared to wheat, local maize populations are more present in production in the wheat subsoil. This local germplasm, created through centuries of maintenance and improvement by farmers in BiH, shows exceptional adaptability to different climatic conditions across the country, making it a valuable reservoir of genetic material for potential breeding programs. The conservation and improvement of these resources could significantly contribute to the development of improved maize varieties resistant to climate change, thereby improving agricultural sustainability and food security in the country. This rich genetic heritage represents an untapped opportunity for scientific research and innovation, highlighting the importance of systematically valuing, conserving and utilizing local maize and wheat populations in BiH. In this way, these crops could play an even greater role in supporting traditional agriculture and stimulating economic growth. The conservation and maintenance of genetic resources play a key role in ensuring food sovereignty, preserving agricultural biodiversity and promoting sustainable food systems. By conserving these valuable resources, we not only protect the foundation of our food security but also create opportunities to enrich and diversify the gastronomic offer. This diversity has the potential to inspire innovation in the culinary arts, elevate the gastronomic experience and strengthen local and regional identities through unique tastes and traditions. Moreover, the conservation of genetic resources opens the door to the development of gastronomic tourism. Tourists are increasingly attracted to destinations that offer authentic culinary experiences, rooted in the use of indigenous crops and traditional recipes. By highlighting the cultural and ecological significance of local genetic resources, regions can attract visitors eager to explore their rich heritage, while supporting sustainable development. In turn, this contributes to rural economic growth, fosters community resilience and raises awareness of the importance of conserving biodiversity for future generations.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	Author 1	Author 2
Conceived and designed the research or analysis	Yes	Yes
Collected the data	Yes	Yes
Contributed to data analysis & interpretation	Yes	Yes
Wrote the article/paper	Yes	Yes
Critical revision of the article/paper	Yes	Yes
Editing of the article/paper	Yes	Yes
Supervision	Yes	Yes
Project Administration	Yes	Yes
Funding Acquisition	Yes	Yes
Overall Contribution Proportion (%)	50	50

Funding
No funding was received from any source to conduct this research or to write this paper.

Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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(Optional) PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
The author(s) has/have NOT complied with PRISMA standards. It is not relevant in case of this study or written work.

Competing Interests/Conflict of Interest
Author(s) has/have no competing financial, professional, or personal interests from other parties or in publishing this manuscript. There is no conflict of interest with the publisher or the editorial team or the reviewers.

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